Pictured Rocks National Lakeshore
Natural Resource Science Strategy

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Table of Contents

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I. INTRODUCTION

A. Purpose

The framers of the 1916 Organic Act believed preservation was essential for national parks "*to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*" (16 U.S.C.A. Sec. 1). Robert Stanton, fifteenth Director of the National Park Service, stated, "Preserving our natural resources far into the future now requires active and informed management based on sound science."

The Natural Resource Challenge (the Challenge), initiated in 1999, established innovative programs involving Inventory and Monitoring (I&M) Networks, Cooperative Ecosystem Studies Units (CESUs), Exotic Plant Management Teams, and Research Learning Centers to coordinate logistical and other support for many research and other science-based efforts in the national park system. In a few program areas, such as air and water resources, the Challenge has increased support through specialized staffing. National Park Service units continue to receive research and technical assistance through partnerships with the U.S. Geological Survey (USGS) and other agencies. Pictured Rocks National Lakeshore (PRNL) will further the Challenge and other science programs by identifying and setting priorities for future research and communicating that information internally among staff and networks, the regional office, and the Washington Office, and externally to partner agencies and organizations.

The strategy described in this document provides a framework for accomplishing these goals under the guidance of the Midwest Region Science Strategy. Specifically, this document:

- Describes Science and Natural Division programs and cooperating organizations;
- Summarizes important natural resource and management issues facing PRNL;
- Identifies science goals and proposes strategies to increase scientific research and its application; and,

B. Science and Natural Resource Programs and Cooperating Organizations

Natural resources of PRNL and their science-based management are the central focus of the Science and Natural Resource Division program, supported by its staff and several cooperating natural resource programs. The supervisory biologist of Science and Natural Resources reports to the Superintendent of PRNL, and has staff that provide technical and policy assistance to PRNL and serve as liaisons with other NPS units, Midwest Regional Office natural resource staff, the Washington Office natural resource divisions: Air Resources, Biological Resources, Geological Resources, Natural Resource Information, Water Resources, and cooperating agencies and institutions. Science and Natural Resource personnel, working with PRNL staff, provide recommendations in making science-based decisions supported by National Park Service policy. Additional tasks for which the Science and Natural Resource Division is responsible include:

- Coordinating the development of the Resource Stewardship Strategies,

- Managing the natural resource funding sources of the Servicewide Comprehensive Call,
- Reporting annually to the Washington Office on recovery of threatened and endangered species, research conducted in parks, and Challenge accomplishments,
- Participating in regional and national workgroups or advisory groups on natural resource issues, as appropriate.
- Reviewing, approving, and tracking Research Permits,
- Tracking and reporting results toward Strategic Plan goals under the agency Government Performance and Results Act (GPRA),
- Annual reporting of National Natural Landmarks as assigned.

The **Cooperative Ecosystem Studies Unit (CESU)** in the Midwest Region serving PRNL is the Great Lakes-Northern Forest, hosted by the University of Minnesota, Twin Cities (St. Paul campus). This CESU is staffed by a National Park Service research coordinator who reports to the Associate Regional Director, Natural Resource Stewardship and Science. The CESU program maintains an extensive network of agency, university, and organization partners that provide the Midwest Region additional skills and capabilities, particularly in support of I&M activities.

The **Inventory and Monitoring (I&M) Network** in the Midwest Region that serves PRNL is the Great Lakes Network of nine parks, headquartered at Ashland, Wisconsin. The I&M Network coordinator is supervised by a Regional I&M coordinator stationed at the Regional Office, but the workload and agenda of the network is determined by the parks it serves. The network has a decision-making process that is stipulated in a charter signed by all superintendents in the network. The network has a Board of Directors, comprised of park superintendents from network parks, that provides program consultation and approves actions of the network coordinators. It also has a Technical Committee, which reviews and makes recommendations for conducting inventory and monitoring projects. The network parks provide operational and logistical support to these programs. Network staff include data managers, quantitative ecologists, and other subject experts responsible for the development and implementation of long-term monitoring for "vital signs," as well as compiling, cataloging, and coordinating natural resource inventories.

The Midwest Region has two **Exotic Plant Management Teams**. One team is co-located with the Great Lakes I&M Network in Ashland, Wisconsin, and serves eight parks in the Great Lakes region, including PRNL. The Exotic Plant Management Team Coordinator is supervised by the Chief, Natural Resource Stewardship, in the regional office, but the workload and agenda of each team is determined by the parks they serve. The teams work collaboratively with parks, other land management agencies, federal, state, and local governments, and private landowners to control invasive exotic plant species. In addition, the teams conduct restoration projects involving seeding of native grasses, forbs, and legumes.

The **Great Lakes Research and Education Center,** located at Indiana Dunes National Lakeshore, facilitates and coordinates research in 10 national parks in the western Great Lakes region including PRNL. The Center establishes public-private partnerships and collaborative efforts to conduct research to enhance natural and cultural resource management, to communicate scientific information to the public, and to foster greater public support for science-based management decisions. The Center works cooperatively with the Associate Regional Director, Natural Resource Stewardship and Science.

The **U. S. Geological Survey** is the research arm of the Department of Interior and has a research scientist stationed in or near several parks in the region, including a research ecologist at PRNL. The USGS is one of

three agencies that have joined all of the CESUs as an agency partner. The NPS and USGS jointly administer the USGS Natural Resource Preservation Program (USGS NRPP) and other USGS funds targeted for research and technical assistance in parks.

C. Natural Resources of Pictured Rocks National Lakeshore

Climate

The lakeshore is located approximately 46 degrees north latitude and 86 degrees west longitude. The coldest months average well below 0 C (32 F) and the warmer months about 22 C (70 F). Lake Superior greatly ameliorates temperature extremes, slowing spring warming and the onset of winter. The average date of the last freezing temperature in spring is June 8, and the average first fall freeze is September 23; however, freezing can occur during any month. The frost-free period, or growing season, averages 107 days annually. Lake Superior's presence also increases precipitation in the lakeshore. Annual precipitation averages 79 cm (31 inches); annual snowfall is 320 cm (126 inches). Snow generally covers the ground from late November through late April or early May.

The area is within the second-most cloudy region of the United States, characterized by an annual mean cloud cover of 70 percent. Much of the cloudiness occurs in autumn and winter and can be attributed to cool air flowing over Lake Superior being warmed along the shore and forming clouds. This condition also often results in rain, fog, and snow. Spring is relatively clear due to the cold water surface of the lake.

The prevailing wind is from the west, with average velocities ranging from 12 to 15 kilometers per hour (7 to 9 mph). High winds and storm conditions on Lake Superior are not uncommon. The highest recorded one-minute wind speed is 98 kilometers per hour (59 mph).

Geology/Geomorphology

Geological history recorded in the sedimentary rocks and surficial deposits of Pictured Rocks is limited to two widely separated intervals of geologic time, the Late Precambrian, Cambrian, and Early Ordovician Periods (500-800 million years before present) and the Late Quaternary Period (2 million years before present to the present). During the Cambrian and Early Ordovician periods, sediments were deposited in the shallow seas and near-shore deltas that covered what is now northern Michigan. These deposits became the sandstone units that are exposed within Pictured Rocks. Except for their exposure near Lake Superior, these units are presently covered by a veneer of Quaternary glacial drift.

Bedrock is best observed in the western one-third of the lakeshore where cliffs rise up to 60 m (180 feet) from Lake Superior. These extend along the lake about 27 km (17 miles) from Munising to Beaver Basin. For a short distance inland from the escarpment, bedrock is occasionally exposed.

The Jacobsville Formation, of Late Precambrian age, is the oldest formation exposed in the lakeshore. It is fluvial/lacustrine, feldspar-rich quartz sandstone, deep red in color with white mottling. Only the top few feet of the formation rise above lake level within Pictured Rocks (e.g., vicinity of Au Sable Point). This formation was quarried for building stone in the late 19th century. The western side of Grand Island, just west of Pictured Rocks within the Hiawatha National Forest, features spectacular Jacobsville cliffs.

The Mid to Late Cambrian, light grey to white Munising Formation lies unconformably above the Jacobsville. The Munising Formation probably represents a complex shoreline/shallow water environment that was influenced by fluvial, wave, tidal, and aeolian processes. The Munising is divided into three members: the basal conglomerate, the hard Chapel Rock sandstone, characterized by large, sweeping cross beds and the crumbly Miners Castle sandstone.

Capping the easily eroded Miners Castle Member of the Munising Formation in the western half of the Pictured Rocks, is the resistant Early Ordovician Au Train Formation. The Au Train Formation is a light brown to white dolomitic sandstone that lies above the distinctive caprock above the lip of Munising and Bridalveil Falls.

Fossils are completely absent from the Jacobsville Formation and uncommon in the Munising Formation; fragments of trilobites have been found in the Miners Castle member. The Au Train contains Middle Ordovician cephalopod and gastropod fossils.

Structurally, Pictured Rocks lies along the northern edge of the Michigan Basin. Thus, sedimentary bedding dips gently toward the south. Strata also rise very slightly eastward in the vicinity of Pictured Rocks so that the Jacobsville, which is below lake level at Miners Castle, is well exposed to the east of Hurricane River Campground, at Au Sable Point, and in the gorge at Sable Falls.

During the Pleistocene epoch, ice sheets of all four North American glacial stages advanced and retreated through the area. The Valders advance, one of the last substages of the Wisconsinan glacial period, wiped the surface clean and left only its record about 12,000 years ago. A brief re-advance of ice, the Marquette substage, occurred 10,000 years ago in northern Upper Michigan.

Melting of glacial ice within the Superior Basin produced huge rivers that deposited millions of tons of pulverized rock rubble in various configurations to the south of the Superior basin. A sheet of outwash, of varying thickness, was deposited along the south edge of Pictured Rocks between Wetmore and Seney by southward flowing "braided" glacial streams. The material underlying the present-day Kingston Plains was deposited in this way. Kingston and Nevins are examples of "kettle hole lakes" within the outwash. The Grand Sable Banks near Grand Marais perhaps originated as a glaciofluvial crevasse filling or kame terrace.

Meltwater carved several channels into Cambrian sandstone bedrock; the most prominent of these are now occupied by Chapel Creek and Mosquito River and by Beaver Basin. As ice retreated completely from the Superior Basin, water levels in the basin receded rapidly northward leaving the Pictured Rocks area "high and dry" about 9500 years ago. This occurred as outlet channels to the east remained at low levels due to the recent loading of glacier ice.

Between 5,000 and 4,000 years before present, "isostatic rebound" of the earth's crust from its "depressed" state began to accelerate as land was relieved of the huge weight of the ice sheets. The rise of the outlet of ancestral Lake Superior (at North Bay, Ontario) caused lake level to rise relatively quickly to a level roughly 13 m (40 feet) higher than present Lake Superior. This high lake stand has been designated Glacial Lake Nipissing. Slowing of rebound, downcutting of channels through unconsolidated material, shifting of outlets to the south, and climatic change subsequently caused a lowering of Lake Superior to near its present level.

As lake levels rose about 4,700 years before present, the Grand Sable Banks were destabilized and part of the glaciofluvial deposit was reworked by wind to form the Grand Sable Dunes. During the Nipissing "high stand," Chapel Rock and Miners Castle as well as many less prominent features were carved into the Cambrian sandstone by wave action. Beaver, Trappers, Little Beaver, Chapel, Little Chapel, and Miners Lakes represent embayments on ancient Lake Nipissing. As erosion lowered the Lake Nipissing outlet to the modern Lake Superior level during a 1,600 year period, lake currents deposited a succession of parallel beach ridges from the Nipissing level to the present beach. These closely spaced ridges which form a "corrugated plain" are evident in the vicinity of Au Sable Point, along the trail from Little Beaver Lake Campground to Lake Superior, on Sand Point, and on the tombolo between Trout and Murrays Bay on Grand Island.

Soils

The soils of Pictured Rocks reflect the area's geologic background, topography, climate, and vegetative influences. The two dominant soil-forming elements are parent material and drainage conditions.

Soil types of the lakeshore can be grouped together as follows: upland loams, plains sands, sandy loams and sands, upland stony loams and sands, lakeshore soils, swamp and wetland soils, and organic soils.

Upland loam soils are underlain by gravels at 15 to 30 cm (6 to 12 inches), with stony clays below gravel. They are generally well drained in surface layers and are moderately productive. The soils are distinguished by large amounts of limestone in the lower gravels. Local areas are stony. Upland loams occur in the southwestern portion of the lakeshore.

Most of the plains sands occur in land that is level to slightly rolling. All these soils are underlain by dry loose sand several feet deep. These soils are well drained and low in fertility. Plains sands occur throughout the Kingston Plains and extend into the southeastern and southcentral portions of the inland buffer zone.

Hilly terrain and stony conditions occur throughout the sandy loams and sands soils. The surface soils, 30 to 40 cm (12 to 16 inches) deep, are underlain by leached sands, which are easily penetrated. Some clays occur locally in the subsoil. Sandy loams and sands soils occupy the comparatively high, hilly upland areas in the eastern sections of the lakeshore, in the western portion of Beaver Basin, and southwest of Sand Point.

Bedrock (sandstones and limestones away from Lake Superior) is present at slight depth throughout upland stony loams and sands. The profile is poorly developed, stones are very common, and many inclusions of clay and clay hardpan are present. Upland stony loams and sands soils are present in the rolling terrain from Beaver Lake to Sand Point.

Sand, gravels, and stones are indicative of lakeshore soils. They are generally excessively dry due to rapid subsurface drainage. Active and stabilized dune areas are included. Lakeshore soils occur at Sand Point and extensively along the northern shore of the national lakeshore from Miners Beach to Sable Creek.

Swamp and wetland soils have black muck surface layers with clay or sand beneath. The water table is from 0.3 to 1 m (1 to 3 feet) below the surface, and the soils are almost permanently waterlogged. Water-tolerant trees, shrubs, and herbaceous plants grow well in these soils. Swamp and wetland soils are present in bogs, marshes, and in narrow floodplains along major stream channels.

Organic soils are mucks and peats up to ten feet deep. Water-tolerant vegetation grows well in this soil type.

Aquatic Resources: Ground Water Hydrology

The most accessible sources of groundwater over a large part of Alger County are the deposits of glacial drift. These range from clayey till and lake deposits of low permeability to highly permeable sand and gravel outwashes. The most extensive outwash in the national lakeshore is the Kingston Outwash Plains. The thickness of the outwash deposits of the Kingston Plains probably exceeds 30 m (100 feet). Some small wells in the area are yielding in the range of 20 gallons per minute (gpm).

Beds of sand that were deposited in glacial lakes also are a source of water for wells. Glacial lake deposits in the lakeshore occur in a strip along the shore of Lake Superior. Most of the wells tapping the lake deposits are shallow-driven and commonly provide a satisfactory and inexpensive water supply. Ten to twenty gpm can be obtained from properly constructed wells tapping sandy lake deposits. Where outwash or beach-deposited sand and gravel are present, wells may yield 100 gpm.

The Grand Sable Dunes are perched dunes situated at the northeastern end of the national lakeshore. They are located above the groundwater, are not saturated, and thus do not yield water to wells. The dune sands are very permeable, and most of the precipitation falling on them infiltrates to recharge the under-lying aquifers.

The Munising sandstone underlies nearly all of the lakeshore. This formation forms the most extensive aquifer throughout the area, but it is tapped by only a few wells. This apparent paradox is due to the fact that in most of the area it is overlain by other aquifers that can be tapped at shallower depths.

The Jacobsville sandstone underlies all of Alger County. In much of the county it has little potential as a source of water; however, at Au Sable Point the sandstone is at or near the surface.

The groundwater yielded by outwash and lake deposits, Munising sandstone, and Jacobsville sandstone meets federal primary safe water drinking standards; some of the groundwater contains objectionable amounts of iron. The groundwater from the outwash and lake deposits is soft to moderately hard, whereas Munising sandstone and Jacobsville sandstone water is moderately hard to hard.

Aquatic Resources: Surface Water Hydrology

Lake Superior is the major water body in the area and forms the northern border of Pictured Rocks National Lakeshore. The lake has a maximum depth of 420 m (1,335 feet) but is relatively shallow near the Pictured Rocks shoreline. Its surface lies at an elevation of 187 m (600 feet) above sea level. The maximum recorded tidal/storm elevation was 604.3 feet. In recent times lake level has varied on the order of several feet due to changes in precipitation and evaporation.

The more prominent inland lakes are Grand Sable, Beaver, Little Beaver, Chapel, Little Chapel, Miners, Trappers, Legion, Kingston, and the Shoe Lakes. These lakes range in size from 762 acre Beaver Lake to 10 acre Miners Lake. Most of the inland lakes, with the exception of Grand Sable Lake and Chapel Lake, are quite shallow (3 to 6 m, 10 to 20 feet in depth), but have lengthy flow-through rate times. Many of the lakes are mesotrophic and have Secchi disk (water transparency) readings between 2 and 5 m. The intensive

logging in the area and recurrent fires may have caused erosion and nutrient deposition in the lakes. Miners Lake and Little Chapel Lake exhibit the greatest trend toward eutrophication. The most oligotrophic lakes are Legion Lake, the Shoe Lakes, and Grand Sable Lake. The inland lakes vary considerably in their water chemistry, but many can be classified as productive, brown, alkaline water lakes.

Although Legion, the Shoe, Kingston, and Trappers Lakes are alike in that they are closed basin lakes (having no streams flowing in or out), they were formed in different ways. Kingston, Legion, and the Shoe Lakes are kettle lakes, formed by the melting of blocks of ice that separated from the retreating glacier about 10,000 years ago. In particular, Legion Lake and the Shoe Lakes lie high on the watershed divide between Lake Superior and Lake Michigan and receive very little groundwater input of elements like calcium, magnesium, and silica. They are acidic (pH 4.8-5.1), poorly buffered, and have relatively high Secchi disk readings (5-9 m).

Trappers, Beaver, and Little Beaver Lakes are located in Beaver Basin, which was once an embayment of Lake Superior when the lake level was considerably higher. As the lake level dropped, sandy beach ridges separated the lakes from Lake Superior, creating these relict lakes. Miners Lake lies along the Miners River in Miners Basin, which was also an embayment of Lake Superior during higher lake levels approximately 5,000 years ago.

Chapel Lake is elongate and was likely formed by a large plunge pool in a glacial meltwater channel. Its southern basin is about 43 m (140 feet) deep, extending into the Jacobsville Sandstone, and is shallow toward the northern end, where rooted, aquatic plants emerge at the surface. Chapel Lake is meromictic; the deepest layer of water does not mix with the upper lakewater during spring and fall turnovers. The water below approximately 18 m (60 feet) is cold, dense, and anoxic (extremely limited dissolved oxygen).

The rivers and streams that flow to Lake Superior through Pictured Rocks have a relatively short and have steep gradients, because the peninsular divide in the region is much closer to Lake Superior than to Lake Michigan. The steep gradient includes waterfalls, where the streams drop over the escarpment. The more prominent waterfalls within the lakeshore are Munising, Miners, Mosquito, Bridalveil, Chapel, Spray, and Sable Falls. Especially noticeable at many of the waterfalls is the brown color of the water due to humic acids that originate from the wetlands in the headwaters.

The discharge (rate of flow) of the streams is highest in the late spring and early summer following snowmelt. In addition, these streams are very responsive to rainfall, and will rise immediately following a significant rain. Discharge can double for a day or so after significant rainfall. Miners River is the longest and largest river in the lakeshore. Its discharge near the mouth averages 46 cubic feet per second during June and drops to an average of 21 cubic feet per second in late summer and fall. The Hurricane and Mosquito Rivers have similar discharges during spring and early summer (19 cubic feet per second), but that of the Mosquito River drops more significantly as the summer progresses. Munising, Chapel, Section 34, Spray, Sevenmile, Beaver, Rhody, Sullivan, and Sable Creeks are shorter and carry less water. Beaver Creek and Grand Sable Creek flow from lakes and have more stable discharges because the lakes buffer the effects of precipitation. The temperature of these two streams is higher than the other streams from July until the fall turnover, because the lakes absorb the sun's radiant energy and the warmest water at the surface supplies the streams.

The substrates of the streams are variously composed of cobble/gravel, sand, and bedrock. The substrate in depositional areas along the banks and upstream from beaver dams is mud/silt. Most pools are formed by the force of water flowing over trees that have fallen into the streams, but some are lateral scour pools that form in the bends of the streams. Cobble/gravel habitats are common and provide habitat for diverse benthic invertebrate populations.

The quality of water of the inland lakes, rivers, and streams is directly related to the watersheds they drain. The majority of the shoreline zone's rivers and creeks have headwaters that occur in the inland buffer zone and the surrounding region. Management of these areas can affect the quality of the national lakeshore's water bodies.

Aquatic Resources: Biological Communities

In the lakes, communities of small animals and plants are found suspended in the water (zooplankton and phytoplankton) and living in or on the upper sediments (benthos).

Zooplankton communities vary among the lakes. In addition, these communities vary seasonally and with depth within the same lake. To date, 35 taxa of cladocerans (water fleas), 11 species of calanoid and cyclopoid copepods (aquatic crustaceans), and two genera of rotifers (aquatic invertebrates) have been identified from eight lakes in Pictured Rocks. As is typical, one cladoceran species, one calanoid copepod species, and one cyclopoid copepod species dominate the zooplankton community in a lake, with other species occurring at much lower relative frequencies. Dominant zooplankton taxa include the cladocerans Bosmina longirostris, Eurycercus lamellatus, Daphnia galeata mendotae, Holopedium gibberum, and Pseudochydorus globosus; the calanoid copepods Skistodiaptomus oregonensis, Epischura lacustris; the cyclopoid copepods Cyclops vernalis and Diacyclops bicuspidatus thomasi; and rotifers of the genus Keratella.

The spiny water flea, Bythotrephes cederstroemi, is an exotic cladoceran that was first observed in the Great Lakes in 1984 and was first collected from Beaver Lake in 1997 and from Grand Sable Lake in 2002. With its long spine, it is visible to the naked eye (1/4 to 1/2 inch in length), and it competes with native cladocerans and certain fish (yellow perch, for example) for its prey, which are copepods, other cladocerans (i.e. Daphnia), and rotifers. Although fish consume it, young perch less than 2.5 inches will avoid eating it because of its large, irritating spine. The resting (over-wintering) eggs are capable of withstanding desiccation and extremes of temperature. The gear of anglers and live fish bait may be responsible for the transport of the spiny water flea from lake to lake, because the resting eggs can be transported in stomachs of fish and remain viable after excretion. Little is known about specific effects of the spiny water flea on the fisheries of inland lakes, but it certainly poses a threat to the food web.

The phytoplankton identified from the inland lakes of Pictured Rocks include at least 51 taxa of blue-green algae (Cyanophyta), dinoflagellates (Pyrrhophyta), yellow-brown algae (Chrysophyta), diatoms (Bacillariophyta), and green algae (Chlorophyta). Seasonal fluctuations occur in the relative densities of these unicellular plants. Dominant taxa include the diatoms Asterionella formosa, Fragillaria intermedia, Aulocoseira islandica, and Tabellaria fenestrata and the blue-green algae Aphanizomenon flos-aquae, Aphanocapsa rivularia, Chroococcus limneticus, and Lyngbya birgei. The filamentous green alga, Bulbochaete sp., is found attached to submerged logs in softwater Legion Lake. Diatoms of this acidic lake are typically benthic, and, due to limited dissolved silica, are not preserved in the sediments.

One hundred eight taxa of benthos have been identified from the inland lakes of Pictured Rocks. These include representatives of water bugs (Hemiptera), water beetles (Coleoptera), caddisflies (Trichoptera), butterflies (Lepidoptera), dragonflies/damselflies (Odonata), mayflies (Ephemeroptera), fishflies/alderflies (Megaloptera), true flies (Diptera), aquatic earthworms (Oligochaeta), leeches (Hirudinea), water bears (Tardigrada), scuds (Amphipoda), seed shrimp (Ostracoda), aquatic sow bugs (Isopoda), snails and limpets (Gastropoda), and clams (Pelecypoda), crayfish (Decapoda), freshwater sponges (Porifera), and moss animalcules (Bryozoa). The benthos from the deepest regions of the lakes differs from those of the shallower, near-shore areas. Typical of northern brown water lakes, the benthic communities of deep water are not diverse and are often dominated by midge larvae called bloodworms (Diptera, Chironomidae). The nearshore benthic communities are much more diverse.

The flowing waters of Pictured Rocks are habitat for a considerable diversity of organisms. One hundred seventy-three taxa of aquatic macroinvertebrates have been identified from the streams of Pictured Rocks. These include larval and/or adult water bugs (Hemiptera), water beetles (Coleoptera), caddisflies (Trichoptera), stoneflies (Plecoptera), dragonflies/damselflies (Odonata), mayflies (Ephemeroptera), fishflies/alderflies (Megaloptera), true flies (Diptera), aquatic earthworms (Oligochaeta), scuds (Amphipoda), leeches (Hirudinea), snails and limpets (Gastropoda), and crayfish (Decapoda). The collection of three species of riffle beetles (Coleoptera, Elmidae), Macronychus glabratus (most often found on waterlogged wood), Optioservus fastiditus and Stenelmis crenata (both found in gravel substrates) during the mid 1990's, are records for Alger County. They extend the known range of these species from northeastern Wisconsin, the Lower Peninsula of Michigan, and Marquette County, Michigan. In addition, freshwater sponges (Porifera), hydra (Coelenterata), bryozooans, and planaria (Turbellaria) are not uncommon.

Chapel Creek, Section 34 Creek, Little Beaver Creek, and Mosquito River are home to Batrachospermum, a red algae visible to the naked eye that thrives in cold, running waters. The filamentous green algae, Ulothrix and Spiroyra, intertwine and grow into strands up to several meters long in certain reaches of several streams where there is bedrock substrate (e.g., near the mouth of Mosquito River). Attached microscopic diatoms (Bacillariophyta) are prevalent throughout the streams.

Beaver activity is present on all but the smallest creeks. Their dam building is common in the wetland headwaters of the streams, but dam building occurs further downstream on the larger streams as well. Beaver ponds open the forest, adding a warmer, slower gradient, and finer substrate environment for aquatic life.

Aquatic Resources: Fisheries

The waters of Pictured Rocks are relatively sterile and unproductive in terms of sustaining large biomasses of fish and associated communities. They do support populations of cool water game fish and trout, and can supply a limited amount of fish for angler consumption. Major cool water game species include smallmouth bass (Micropterus dolomieu), northern pike (Esox lucius), walleye (Stizostedion vitreum), yellow perch (Perca flavescens) and non-native smelt (Osmerus mordax). Typical trout species found in Pictured Rocks are brook trout (Salvelinus fontinalis), lake trout (Salvelinus namaycush), and non-native rainbow trout or "steelhead" (Salmo gairdneri).

Other species found in lakeshore waters include white sucker (Catostomus commersoni), a variety of minnows, darters, sculpins, dace, and sunfish. About 53 species of fish are present in lakeshore waters, including the nearshore waters of Lake Superior.

Since 1997 coaster brook trout, a strain of brook trout that spends much of its life cycle in Lake Superior, have been stocked in Mosquito and Hurricane Rivers and Sevenmile Creek five times. Brood stock from Tobin Harbor (Isle Royale) strain has been reared at U.S. Fish and Wildlife Service hatcheries at Iron River, Michigan, and Genoa, Wisconsin. Understanding the timing and duration of migrations of coasters from the streams to Lake Superior and their return to the streams at spawning is the subject of several graduate research projects at Northern Michigan University. State of Michigan fishing regulations now protect brook trout in these three streams with a shortened season and expanded size and catch limits to protect spawning runs. It is hoped that this restoration program, in cooperation with U.S. Fish and wildlife Service, Michigan Department of Natural Resources, and Northern Michigan University will lead to self-sustaining populations in suitable Pictured Rocks streams, in concert with Lake Superior-wide restoration program of the Great Lakes Fishery Commission.

Prior to the establishment of the national lakeshore, many species were stocked into (including non-natives) and removed from waters of the area by the Michigan Department of Natural Resources. The NPS is now seeking to manage for a more native fishery. Stocking of walleye in Beaver Lake by Michigan Department of Natural Resources (DNR) ceased in 1998 after several studies found limited spawning habitat in the lake. Lake trout will continue to be stocked in Grand Sable Lake through 2005 under a ten year agreement with DNR. The management goal is to foster naturally reproducing populations of native fish.

Vegetation

Pictured Rocks lies within the northern hardwood/hemlock/white pine region of the eastern deciduous forest. This forest type is transitional between the more homogeneously deciduous forests to the south and the coniferous boreal forests to the north. About 80 percent of the lakeshore is dominated by upland northern hardwoods. Dominant species are American beech (Fagus grandifolia), sugar maple (Acer saccharum) red maple (Acer rubrum), yellow birch (Betula allegheniensis), eastern hemlock (Tsuga canadensis), and eastern white pine (Pinus strobus).

On coarse outwash and coastal sands (about 10 percent of the lakeshore), red pine (Pinus resinosa), white pine and jack pine (Pinus banksiana) are dominant. Successional stands within these soils contain considerable amounts of paper birch (Betula papyrifera) and trembling aspen (Populus tremuloides). Ground and crown fires influenced this pine-dominated vegetation prior to European settlement.

Scattered small patches of wetter habitat occur on upland benches and in poorly drained topographic lows (about 10 percent of the lakeshore) These contain boreal forest elements such as black spruce (Picea mariana), white spruce (Picea glauca), northern white cedar (Thuja occidentalis), and tamarack (Larix laricina). Larger white cedar glades within Pictured Rocks are southwest of Grand Sable Lake, south of Au Sable Point, along the southern and western edges of Beaver Basin, and east and south of Miners Basin.

Bogs within Pictured Rocks are usually filled-in lake beds having a sphagnum base and containing ericaceous shrubs, e.g., leatherleaf (Chamaedaphne calyculata), bog rosemary (Andromeda glaucophylla), bog laurel (Kalmia polifolia), and cranberries (Vaccinium macrocarpon; V. oxycoccos). Several species of

orchids are found throughout the bogs. Four major bog areas have been located in the lakeshore: a very shrubby one on Sand Point, a filled-in bog northeast of Beaver Lake, several bog pockets around Legion Lake, and a classical bog lake east of Twelvemile Beach campground. The best examples of marshes in Pictured Rocks occur in quiet shallow pockets of large lakes and around the periphery of small lakes, most notably around Miners Lake and Little Chapel Lake.

Forests of Pictured Rocks have undergone significant changes due to logging and to land clearing for agricultural purposes. Logging, exotic disease (e.g., Dutch elm disease) and repeated fires have contributed to change. Cutting of pine began in the mid-1880's and continued into the early 1900's. Several fires in slash subsequently burned over pineland areas. It is assumed that the open "stump prairie" of the Kingston Plains, dominated by hairgrass (Deschampsia flexuosa), poverty oats grass, (Danthonia spicatum) and reindeer lichen (Cladina rangiferina) is a result of these events.

The greatest change in the mixed conifer/deciduous forest has been a decrease in average tree size. Most of the original forest has been either clear cut or selectively cut. The hardwood forests of today are pole to small timber size. In wet areas, many large elm groves have been killed by the Dutch elm disease, and red maple has become more common. There has been relatively little compositional change in the bottomland cedar type.

The Grand Sable Dunes are occupied by a suite of unusual vascular plant species. Six species listed as threatened by the State of Michigan are present. These include dune grass (Elymus mollis), Lake Huron Tansy (Tanacetum huronense), ram's head orchid (Cypripedium arietinum), Douglas' hawthorn (Crategus douglasii), calypso orchid (Calypso bulbosa) and Pitcher's thistle (Cirsium pitcheri). Pitcher thistle, a Great Lakes endemic, is listed as threatened by the U.S. Fish and Wildlife Service (Pitcher's Thistle Recovery Team 2002). The dunes contain a variety of "moonwarts" (Botrychium subgenus Botrychium) and orchids.

Pictured Rocks contains about 618 known species of plants. Of these, about 11 percent may be classified as exotic.

Wildlife

Habitat for two federally-listed wildlife species, piping plover (Charadrius melodus), peregrine falcon (Falco peregrinus) is found within the lakeshore. The gray wolf (Canis lupus) was delisted in 2007. Lynx (Lynx canadensis) has been listed as threatened by the U.S. Fish and Wildlife Service. Critical habitat for lynx has not been identified at this time. Wolves were recently downlisted to threatened by the U.S. Fish and Wildlife Service; the population in the Upper Peninsula is currently about 280. Wolf sign and sightings in and around the lakeshore are not uncommon; no established packs are known to occupy the lakeshore area. Transient animals are observed frequent the area at least during snow-free seasons. Plovers have nested within the lakeshore, most recently in the early 1990's in Grand Marais on the beach north of the Grand Marais Maritime Museum, but the nest was vandalized and they have not nested on lakeshore lands since. Peregrine falcons were released in the lakeshore in 1989 and 1991 as part of a Midwest peregrine reintroduction program. They nested on the cliffs near Grand Portal Point in 1994 and fledged two; gulls are believed to have killed both young shortly after fledging. Since then peregrines have been seen on Grand Island and are believed to be nesting there. In 2001, peregrines had reportedly nested in the Chapel/Grand Portal Point area. An adult pair was observed in this same area during 2002-2007 with up to two young annually. The

bald eagle (Haliaeetus leucocephalus), also recently delisted federally from threatened status, nests within the lakeshore. Three nest territories are known.

State-listed mammalian and avian species present include least shrew (Cryptotis parva), common loon (Gavia immer), merlin (Falco columbarius), and osprey (Pandion haliaetus). The mountain lion (Felis concolor) is believed to have been extirpated in Michigan by the turn of the 20th century, but occasional unconfirmed sightings near the lakeshore and around the eastern Upper Peninsula persist. The trumpeter swan (Cygnus buccinator) is not listed, but was extirpated from Michigan and has been reintroduced in the Upper Peninsula.

Other mammals of interest include American marten (Martes americana), moose (Alces alces), gray fox (Urocyon cinereoargenteus), river otter (Lontra canadensis), fisher (Martes pennanti), badger (Taxidea taxus) and beaver (Castor canadensis). Moose are uncommon in the Upper Peninsula due to the meningial worm transmitted from deer and are rarely seen in the lakeshore. Lynx and gray fox are uncommon. Otter, marten, and fisher were virtually extirpated in the area but have made a comeback. Badger expanded their range from the western prairies as settlement cleared forests; records in the Upper Peninsula are becoming more common; they could occupy old farm fields within the lakeshore. Beaver are common and are important for the major changes their activities bring about to the forest ecosystem.

Other mammals include black bear (Ursus americanus), coyote (Canis latrans), red fox (Vulpes vulpes), bobcat (Lynx rufus), white-tailed deer (Odocoileus virginianus), mink (Mustela vison), muskrat (Ondatra zibethicus), skunk (Mephitis mephitis), raccoon (Procyon lotor), snowshoe hare (Lepus americanus), porcupine (Erethizon dorsatum) and eastern chipmunk (Tamias striatus). Bear and deer are the primary prey species for Upper Peninsula hunters. Porcupine occasionally attack lakeshore structures -- seeking minerals from plywood and salt-impregnated wood.

Extirpated mammalian species include caribou (Rangifer tarandus) and wolverine (Gulo gulo). Caribou historically ranged throughout the Upper Peninsula but were rare by 1850, and last seen around 1910 -- probably disappearing due to habitat changes brought about by human activity.

About 171 species of birds have been observed in the lakeshore. Avian species of interest found within the lakeshore include upland species such as ruffed grouse (Bonasa umbellus), spruce grouse (Dendragapus canadensis), sharp-tailed grouse (Tympanuchus phasianellus), and American woodcock (Scolopax minor); as well as wading birds and waterfowl, including sandhill crane (Grus canadensis), great blue heron (Ardea herodias), and several species of the orders Anseriformes (geese, ducks and mergansers), Podicipediformes (grebes), and Charadriiformes (gulls and shorebirds). The previously mentioned common loon is frequently seen, but not known currently to nest within the lakeshore. Grouse and woodcock are popular species with Upper Peninsula hunters.

Besides the previously mentioned threatened or endangered species (bald eagle, peregrine falcon, merlin and osprey) several species of raptors are found within the lakeshore. These species include northern goshawk (Accipiter gentilis), northern harrier (Circus cyaneus), sharp-shinned hawk (Accipiter striatus), red-tailed hawk (Buteo jamaicensis), barred owl (Strix varia), and other hawk and owl species.

Other common avian species include turkey vulture (Cathartes aura), several species of Orders Piciformes (woodpeckers) and Passeriformes (perching birds), including numerous warblers and other songbirds.

As would be expected at this northern latitude, herpetofauna are not numerous. Only 21 reptile and amphibian species are known to exist within the lakeshore. Among species present besides the state-listed species of special concern wood turtle (Clemmys insculpta) are: American toad (Bufo americanus), spotted salamander (Ambystoma maculatum), spring peeper (Hyla crucifer), leopard frog (Rana pipiens), painted turtle (Chrysemys picta), snapping turtle (Chelydra serpentina), eastern garter snake (Thamnophis sirtalis), and northern water snake (Nerodia sipedon).

Several species insects and gastropods (snails, limpets, and slugs) are found within the national lakeshore. Several threatened, endangered, or species of special concern are known or suspected to inhabit the area. The American burying beetle (Nicrophorus americanus) is listed as endangered and has been identified in Alger County. The threatened Northern Blue butterfly (Lycaeides idas nabokovi) has been identified in Alger County, and its larval host plant, dwarf bilberry (Vaccinium caespitosum) has been documented within the lakeshore.

Air Quality

An assessment during the 1990's, based on lichen flora and elemental analysis, suggested that air quality in the vicinity of Pictured Rocks is good from most standpoints. Although large-scale heavy industry is quite distant from the lakeshore, some long range/global atmospheric transport of pollutants to the Pictured Rocks area has been documented. Acid deposition in the central Upper Peninsula is a well established phenomenon. Long-range transport of toxics/pollutants has apparently influenced other remote park units (e.g., Isle Royale). No baseline information exists on any ambient air quality parameter within the boundaries of Pictured Rocks. There is an ozone monitoring station at Marquette, Michigan, 75 km (45 miles) to the west.

There are several small scale sources of air pollution in the vicinity. The most significant of these is the Kimberly-Clark Corp. paper mill within the city limits of Munising. Impacts of the emissions from this operation on lakeshore resources are generally unknown.

Recreational Values Associated with Natural Resources

As would be expected, the Lake Superior shoreline is the focus of nearly all visitation to the lakeshore. The dramatic land/sea interface (for Lake Superior is essentially a freshwater sea) is a draw to visitors not only for active forms of recreation, but also for more contemplative forms. This demand results in recreational pressure not found at nearby inland recreation sites.

Most visitation to the lakeshore comes in two seasons: winter and summer. The late snowmelt in spring and subsequent wetness limits visitor access to much of the lakeshore. The fall colors attract visitors for a short time, but unpredictable, often cold, rainy or snowy weather after Labor Day through November discourages high levels of visitors. Backpacking, hunting and fishing are important shoulder season (spring and fall) activities in the lakeshore.

July and August are the primary summer visitor months, with approximately 50 percent of the lakeshore's total visitation. While the majority of visitors are drive-through day users who limit their visit to automobile-accessible points of interest, hiking and backpacking are also very popular. The lakeshore has 111 miles of

trails including 43 miles of the North Country National Scenic Trail traversing the entire length of the lakeshore, 46 miles of day use and backcountry trails, and 22 miles of ski trails. Thirteen backcountry campsites and eight group backcountry sites are available, in addition to three drive-in campgrounds

As would be expected, many of the summer activities are water-related. Sand Point Beach (on Lake Superior) and Grand Sable Lake are commonly used by swimmers. Miners and Twelvemile Beaches are also popular areas. Because most of the shoreline is not accessible by automobile, access is by foot or boat, and the popularity of the Pictured Rocks backcountry is largely attributable to its proximity to Lake Superior. Mosquito and Chapel Beaches are very popular backcountry day use areas.

The unprotected nature of the lakeshore shoreline in the face of prevailing northwest winds and the lack of large marinas in the area currently limit vessel use in the lakeshore. Recreational motor boaters and personal watercraft users are common along the length of the lakeshore in Lake Superior. Sea kayaking along the shore has rapidly grown in popularity since 1990; expeditions traversing the lakeshore and camping in backcountry sites have increased dramatically. Fishing, boating, and canoeing on many of the lakeshore's inland lakes is also popular, primarily at Little Beaver, Beaver, and Grand Sable Lakes.

Besides the inherent danger of Lake Superior, unpredictable and often unseasonably cold weather -- as well as abundant mosquitoes and several species of biting flies -- are the primary limiting factors for summer visitors.

D. Natural Resource Management Issues

Multiple anthropogenic factors, including climate change, consumptive uses, alteration of disturbance regimes, and accumulation of contaminants, adversely affect national park resources and associated human values. At the same time, remote locations, inadequate funding, limited staff, limited data, overlapping authorities, and competing needs contribute to the diversity of challenges faced by today's managers of park lands.

- **Exotic plant and animal species.** Exotic and invasive plant and animal species threaten ecosystems in PRNL. For example, spotted knapweed threatens unique plant communities in the Grand Sable Dunes. Fish community damage to lakes and rivers from the exotic sea lamprey and several salmonid species is well documented or under investigation. Recent invasions of other aquatic species, such as the spiny water flea, will likely also be detrimental, and efforts to control them may lead to unforeseen impacts. Exotic insects, including emerald ash-borer, are destructive forest pests, which could threaten composition of eastern deciduous forest community.
- **Land-use change.** Land-use changes including timber harvest, road improvement projects, and human development internal and external to PRNL can adversely affect lakeshore resources, including water quality, biodiversity, natural processes, viewsheds, and soundscapes. Solutions to these problems will require partnerships with adjacent landowners and stakeholders.
- **Water quality.** Overall water quality at PRNL is good. Human activities including timber harvest need to be monitored, particularly in relation to buffer strips along wetlands and streams. Point and nonpoint pollution sources are potential problems to aquatic ecosystems. Periodic assessments of pollutants and heavy metals (e.g., Hg) is necessary in relation environmental bioaccumulation and human health (e.g., fish consumption advisories)

- **Air quality**. Air quality at PRNL is generally considered good. Increases in air-borne pollutants could degrade visibility and threaten the health of ecosystems, park staff, and visitors. Air-borne pollutants are particularly problematic in that sources may be hundreds of miles from the affected park and/or associated with the vehicles of park visitors. Despite our status as Class II Clean Air Areas, PRNL needs to continue assessing potential impacts from long-range atmospheric contaminants.
- **Wildlife management.** Management of wildlife populations at PRNL poses serious challenges for wildlife management in parks. For example, harvest of potentially vulnerable species including black bear, fisher, and marten requires periodic assessments of populations and monitoring of harvest. Also, emerging diseases, such as Chronic Wasting Disease or Avian Influenza, could affect wildlife populations at PRNL and may require monitoring.
- **Rare, threatened, and endangered species**. Although PRNL harbors comparatively few numbers of rare, threatened, and endangered species compared with many other NPS units, several species are notable for their rarity and international restoration efforts. There are numerous issues, often contentious, associated with species recovery and compliance with the Endangered Species Act.
- **Ecological restoration**. Unlike western parks, most parks in the Midwest, including PRNL, were created from private or corporate lands with a history of land conversion. Human activities in the surrounding landscape continue to affect habitat in PRNL. Knowledge assessing the extent of damage and restoration techniques has advanced, yet information gaps remain.
- **Visitor use impacts.** Providing positive visitor experience is a critical part of the NPS mission, and fosters greater public support for the conservation of park resources. Many parks in the Midwest Region are threatened by visitor conflicts and crowding that result in a variety of visitor-caused impacts on resources, such as trail and campsite deterioration; and impacts on wildlife, vegetation, and water resources. Increased visitation and changing visitor demographics increase the need for development of indicators and standards for visitor-caused impacts. Moreover, park planning that emphasizes effective communication of lakeshore resources and values with visitors will aid in mitigating or preventing unacceptable impacts on park resources.
- **Fire effects and fire management.** Alteration of fire regimes in most of the last century has influenced the structure and ecosystem processes of the forests, particularly pine-dominated forests within PRNL. Potential use of fire as a management tool has increased through recent development of a fire management plan, but often prescribed fire does not mimic natural fire frequency or effect. The effectiveness of prescribed fire or mechanical treatments in restoration efforts varies by plant community and may or may not accomplish management goals.
- **Climate change.** The lakeshore is affected by both short-term climatic variations and longer-term shifts. For example, short-term climatic variations such as drought cycles can affect management of rare species, aquatic resources, and restoration efforts. Longer-term climate shifts can affect patterns in land cover and hydrology, as well as the distribution of native and exotic species. Increased efforts to understand the effects of both short- and long-term climate variability are needed.
- **Remaining Inventory and Monitoring Needs.** The Great Lakes I&M Network has conducted inventories of vertebrates and vascular plants. Science and Natural Resources staff have initiated some invertebrate inventories, particularly odonates and lepidopterans. However, invertebrates and non-vascular plants have not been systematically inventoried and more detailed summary and synthesis of monitoring information is needed.

II. NATURAL RESOURCE SCIENCE GOALS

To address critical natural resource issues at PRNL, the Science and Natural Resource Division has developed three over-arching goals:

1. **Communicate science information among PRNL staff, partners, and the public**

   This goal focuses on ways to improve communication, share scientific expertise, enhance communication of research and monitoring findings, and promote understanding of science-based natural resource activities at PRNL.

2. **Identify and address priority science information needs for effective management of natural resources**

   This goal builds on efforts to compile research needs for PRNL. This goal addresses priorities for training and education of Science and Natural Resources staff, identifying emerging science issues, identifying potential funding sources and finding partners that can provide critical information for science-based management of natural resources.

3. **Develop infrastructure and procedures to support a strong science program**

   This goal addresses the infrastructure necessary to develop and sustain a strong science program within PRNL. This goal also addresses staffing and funding.

To be responsive to critical issues and focus on these three goals, the following strategies and action items are recommended.

GOAL 1: Communicate science information among PRNL staff, partners, and the public

STRATEGY 1A: Develop communications infrastructure and strategies

The Science and Natural Resource Division has access to and responsibility for sharing various types of information. The purpose of this strategy is to develop more effective means of sharing information among PRNL staff, partners, and the public. Much of this work would be conducted in cooperation with lakeshore interpretive staff. **Specific action items:**

1. **Provide a forum for park feedback**. Enable the regional office to target technical assistance and communicate guidelines and deadlines through better understanding of park information and science needs. Integrate parks feedback opportunities into the proposed annual meetings and the website.
2. **Develop additional science extension strategies.** Better inform National Park Service staff, partners, and the public of research results. Possibilities include regular e-mail summaries, discussions with

interpretive staff, present project results during all-staff meetings, newspaper or web-based articles, magazine articles, and Resource Reports.

3. **Participate in regional/national conferences**. These could giving presentations at the Western Great Lakes Research Conference, Michigan Invasive Plant Council meetings, and Natural Areas Association conferences.
4. **Assist with PRNL website**. Better use of the Natural Resource portion of the PRNL website, which is infrequently updated and, as a result, likely underused. Facilitate communication to interested parties with a well-maintained, user-friendly website.
5. **Develop mailing lists**. Expedite communication within NPS units in the Midwest Region by developing appropriate emailing lists (e.g., Lotus Notes lists). Such lists could pass information among large groups of people or pose questions of broad management or scientific interest.

STRATEGY 1B: Enhance sharing of natural resource expertise among the staffs of the Regional Office, I&M Networks, CESUs, the Research and Education Center, and parks.

Considerable talent and disciplinary expertise exists among natural resource professionals in parks, the Midwest Regional Office, and the Challenge programs. The region needs to better publicize this expertise and encourage its use. **Specific action items:**

1. **Develop and maintain a directory of expertise.** The directory would show subject-matter skills and interests of all natural resources staff in the Midwest Region and from current or potential partners. This list could be garnered from information collected by MWRO, CESUs and the Great Lakes Research and Education Center.
2. **Support opportunities to share expertise.** Facilitate, promote, and support meetings, scientific conferences or other symposia, as they are critical to sharing natural resource expertise.
3. **Convene issue- or event-based teams to assist parks.** Bring together interdisciplinary teams of experts as appropriate to assess the effects of events such as dam removal, coastal erosion processes, or invasions by exotic species.
4. **Encourage researchers to share results informally.** Often principal investigators provide annual reports with limited interpretation. Encourage investigators to share their results with parks through presentations at the park and at local/regional symposia.

STRATEGY 1C: Communicate research and monitoring findings to lakeshore management and interested partners and stakeholders.

Information from research, monitoring, and inventory activities needs to be communicated internally among the various divisions within the lakeshore to develop planning documents, prepare interpretive material, or implement management actions. Information may need to be synthesized or summarized to communicate with partners. **Specific action items:**

1. **Access scientific information for planning.** Ensure that science information is available for Natural Resource Stewardship and other park-specific planning activities
2. **Publish reports.** Formalize technical report series for PRNL. The Great Lakes I&M Network will provide a process for developing peer-reviewed technical reports which we could adopt. Support the reestablishment of the Midwest Regional technical report series would also be useful. Encourage and support publication of research findings in scientific journals.

3. **Showcase outstanding science.** Develop various ways to acknowledge and communicate interesting or new scientific findings by creating a place for such findings on the MWRO or WASO website (e.g., inside NPS) or comparable newsletter.
4. **Hold regular information exchanges with partners.** Continue discussions about research needs with the USGS and other partners through meetings and informal discussions. Maintain and improve regular exchanges with partners through CESUs, I&M network, and GLREC.

STRATEGY 1D: Use of the Science Committee within the Midwest Region

The Science Committee is a new entity in the Midwest Region and is not yet widely recognized. Take steps to ensure awareness of the Science Committee's role, in particular the focus on synthesizing park research needs within a regional or national context and developing contacts, both internally and with partners, to address science needs. Take advantage of opportunities to make suggestions or recommendations for the Science Committee's annual work plan.

GOAL 2: Identify and address priority science information needs for effective management of natural resources

STRATEGY 2A: Identify additional natural resource inventory needs in parks

The Great Lakes I&M Network has completed inventories for vertebrates and vascular plants. However, invertebrates and non-vascular plants have not been systematically inventoried, even though they are often more numerous and more sensitive to disturbance and pollution. In addition, the periodic reinventory (i.e., monitoring) of documented species needs to be addressed. **Specific action items:**

1. **Summarize recommendations for additional inventories.** Inventory reports often contain recommendations for additional inventories of rare vertebrates and vascular plants not documented in the parks but likely to occur. Use a summary of these recommendations to develop a priority inventory list of taxa for funding requests.
2. **Determine high priority inventory needs for invertebrates.** Determine priority inventory needs for invertebrates, especially those providing essential ecological functions such as pollination, herbivory, and organic matter processing. Do so, through interviews with taxa experts. Seek funding for those inventories.
3. **Conduct additional lichen inventories.** The USGS has done lichen surveys and assessments of air pollution impacts on lichen diversity in at least 12 parks in the region. Determine the need for additional surveys of parks based on air-quality trends and other factors and seek funding.
4. **Re-inventory documented species.** Determine the need for re-inventories of vertebrates and vascular plants at PRNL. Prioritize needs and seek funding.
5. **Conduct all-taxa inventoriy.** Support all-taxa inventory following procedures outlined in the All Taxa Biodiversity Initiative.

Strategy2b: Identify high-priority research and technical assistance needs at PRNL.

The CESUs and Great Lakes Research and Education Center are building catalogs of research and technical assistance needs for parks from a variety of sources. Ensure that research needs at PRNL are provided and current. **Specific action items:**

1. **Identify mandated research and technical assistance.** Identify research and technical assistance mandated by legislation such as the Endangered Species Act and/or by agency policy.
2. **Develop research projects for NPS or collaborative scientists.** Identify potential research important to PRNL. Collaborate with external scientists as appropriate to develop these projects for possible funding from the Servicewide Comprehensive Call or other funding sources.
3. **Develop research projects with U.S. Geological Survey.** Identify potential research of interest to scientists with the USGS and collaboratively develop those projects for possible funding from the USGS Natural Resource Preservation Program, NPS-USGS Water Quality Partnership Program, Science on the DOI Landscape, and other USGS funding sources.
4. **Identify multidisciplinary and multi-park research projects.** Identify research questions requiring multidisciplinary approaches involving one or more parks in addition to PRNL.

STRATEGY 2C: Identify possible emerging science issues

New challenges to effective natural resource management rarely "explode" on the landscape but build relatively slowly as species migrate (e.g., invasive species such as zebra mussels moving west), through environmental change (e.g., periodic drought), and as new knowledge allows detection of issues (e.g., Chronic Wasting Disease). **Specific action items**:

1. **Understand and communicate goals and expectations of Department of Interior (DOI) natural resource initiatives.** Determine how DOI initiatives may affect lakeshore management and communicate that information to appropriate staff.
2. **Identify course offerings**. Develop lists of current topics courses and seminars at CESU universities to identify new issues and directions in natural resource management. Draw these to the attention of lakeshore management and natural resource staff.

STRATEGY 2D: Provide or facilitate training and workshop opportunities for natural resource managers and ecologists.

Effective managers use current information and tools and collaborate with peers to understand the science behind management issues. **Specific action items**:

1. **Seek training opportunities.** Determine available National Park Service training; other agency training and workshops, short courses, and distance learning.
2. **Sponsor science conferences.** Create and promote attendance at science conferences and symposia that focus on emerging topics and ecosystems.
3. **Develop research facilities.** When feasible, support the development of the PRNL research and education center.

STRATEGY 2F: Identify appropriate funding sources and potential project investigators for projects.

The Servicewide Comprehensive Call includes an array of funding sources, each with different selection criteria and target years. Matching a proposed project with the appropriate funding source(s) is often difficult; finding a quality investigator for a funded project may be even more of a challenge. **Specific action items**:

1. **Identify all National Park Service funding sources.** This would include the Servicewide Compreshensive Call and any special initiatives. Communicate this information to lakeshore management and staff.
2. **Identify external funding sources.** Identify partners and potential sources of project funds at USGS, CESU partner universities, and from organizations and companies (e.g., Canon) that have supported science in parks.
3. **Use investigator expertise databases.** Encourage use of investigator expertise databases being developed by the CESUs and PRNL for the identification and selection of project investigators.

GOAL 3: Develop infrastructure and procedures to support a strong science program

STRATEGY 3A: Use expertise available in the MWRO Science Committee.

A Science Committee, composed of staff from various disciplines throughout the Midwest Region, has been established by the Associate Regional Director for Natural Resources Stewardship and Science. This committee will focus on the identification and communication of science needs in individual parks and throughout the Region as stated in the Science Strategy. The committee will develop an annual work plan at the beginning of each calendar year. **Specific action items**:

1. **Promote understanding of the Science Committee.** Ensure that lakeshore personnel are aware of the role and organization of the committee and can easily contact members.
2. **Encourage lakeshore staff to participate in identifying science needs**. Promote collaboration among lakeshore staff through formal and informal discussions to identify lakeshore-specific information needs.
3. **Promote scientific engagement.** Encourage Science and Natural Resource staff to conduct research with university and USGS scientists, including co-authoring manuscripts for publication in peer-reviewed journals.

STRATEGY 3B: Enhance technical expertise of Science and Natural Resource staff through professional development.

Continued professional development is essential for Science and Natural Resource staff to provide scientifically sound leadership, assistance, and information for long-term stewardship. **Specific action items:**

1. **Provide library access.** To ensure that state-of-the-art science continues to be integrated into park resource management, Science and Natural Resource staff need access to current scientific literature.
2. **Support professional development.** Identify professional development priorities (e.g., training, scientific conferences, scholarships, etc.) in annual work plans, and provide at least one professional

development opportunity annually for each Science and Natural Resource professional in the lakeshore.

3. **Encourage involvement in interagency activities.** Promote and support increased presence of Science and Natural Resource professionals on interagency task forces, committees, or similar groups such as the Midwest Invasive Plant Network.

STRATEGY 3C: Recognize scientific achievements and contributions to Pictured Rocks National Lakeshore.

Recognizing the scientific achievements and accomplishments of Science and Natural Resource staff and partners is important. Conducting innovative science, fostering productive scientific partnerships, and using science in management should all be recognized more actively. **Specific action items:**

1. **Support awards, including the regional research award.** Ensure lakeshore-level awards are provided to recognize cases of exemplary science. Encourage nominations for the annual regional research award.
2. **Showcase outstanding science.** Find ways to recognize and publicize new scientific findings. Possibilities include creating a place for such findings on the PRNL or Regional website and working more closely with lakeshore, regional, and national public relations and communications staff.
3. **Recognize stewardship and science efforts across divisions.** Recognize staff in other divisions or those who perform dual roles. These people often make important contributions to natural resource stewardship.
4. **Encourage professional development.** Encourage further training and professional development by offering scholarship awards to outstanding scientists (e.g., encourage Albright-Wirth Grant applications or develop regional scholarship funds).

STRATEGY 3D: Ensure high-quality science products

Procedures are in place to review research permits and project proposals, but the review of final research reports could be improved. A procedure for the review of final reports will ensure that original study objectives are adequately addressed, that interpretations of results are appropriate, and that the final product is of high quality. **Specific action items:**

1. **Provide guidance to researchers.** Develop relationships with researchers and provide early and clear guidance during their research permit applications.
2. **Encourage education/outreach.** In research project plans involving the park and the principal investigators, better facilitate and support education and outreach components.
3. **Formalize peer review process for projects.** For all project syntheses that will not be submitted, adopt the peer-review mechanisms of the I&M Networks and the CESUs.